Functional Monitoring in Stream and Wetland Restoration

June 2024

NATIONAL STREAM RESTORATION CONFERENCE

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Restoring a resilient earth for a modern world

Introduction to Speakers

Agenda:

- **Introduction**
- Performance Standards & Monitoring
- EPA ORISE Proceedings on Dynamic Systems
- OU Research on Robinson Fork

Contributors

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

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1804
OHIO UNIVERSITY

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- Katie Wolff, Regulatory Director
- Mike Sachs, General Manager

Who is RES?

RES is restoring a resilient earth for a modern world, project by project.

- Founded in 2007, inspired by notion that restoration can be a win/win for both humanity and the environment
- Nation's largest ecological restoration company, creating ecological uplift by doubling down on nature's own processes
- Pioneered how to make environmental mitigation markets work with a turnkey, total-stewardship business model
- Innovative ecological problem solvers dedicated to being long-term stewards of the earth

The ecological uplift of a mitigation project helps offset unavoidable impacts of infrastructure projects like highway expansions.

Performance Standards & Monitoring

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Goals

Compensatory Mitigation & Ecological Uplift

- Restore and preserve self-sustaining, functional streams, wetlands, and riparian corridors
- Replace the functions and values lost from adverse impacts
- Restoration of an integrated and dynamic stream and floodplain system
  - Restored localized groundwater aquifers and reconnected floodplains to the water table and streams
  - Diversified habitat while also creating a hydrologic system that allowed for the retention of nutrients, stream bed material, and organic carbon.

Table 2: Credit Release Summary		
Project Phase	Stream Credit Release Requested	Wetland Credit Release Request
Administrative Release (R1)	11,668.94	7.33
Administrative Modification based on Final Design (R2)	2,547.15	(1.73)
1st As-Built Release (R2)	5,768.47	2.00
2nd As-Built and Monitoring Release (R3)	14,753.09	6.86
3rd As-Built and Monitoring Release (R4)	35,082.75	12.94
4th Monitoring Release (R5)	15,476.12	6.24
5th Monitoring Release (R6)	9,213.67	9.54
Current Total Releases	94,510.19	43.18
Remaining Releases	**0.00**	**1.18**
Current Requests (R7)	Not Applicable	1.18

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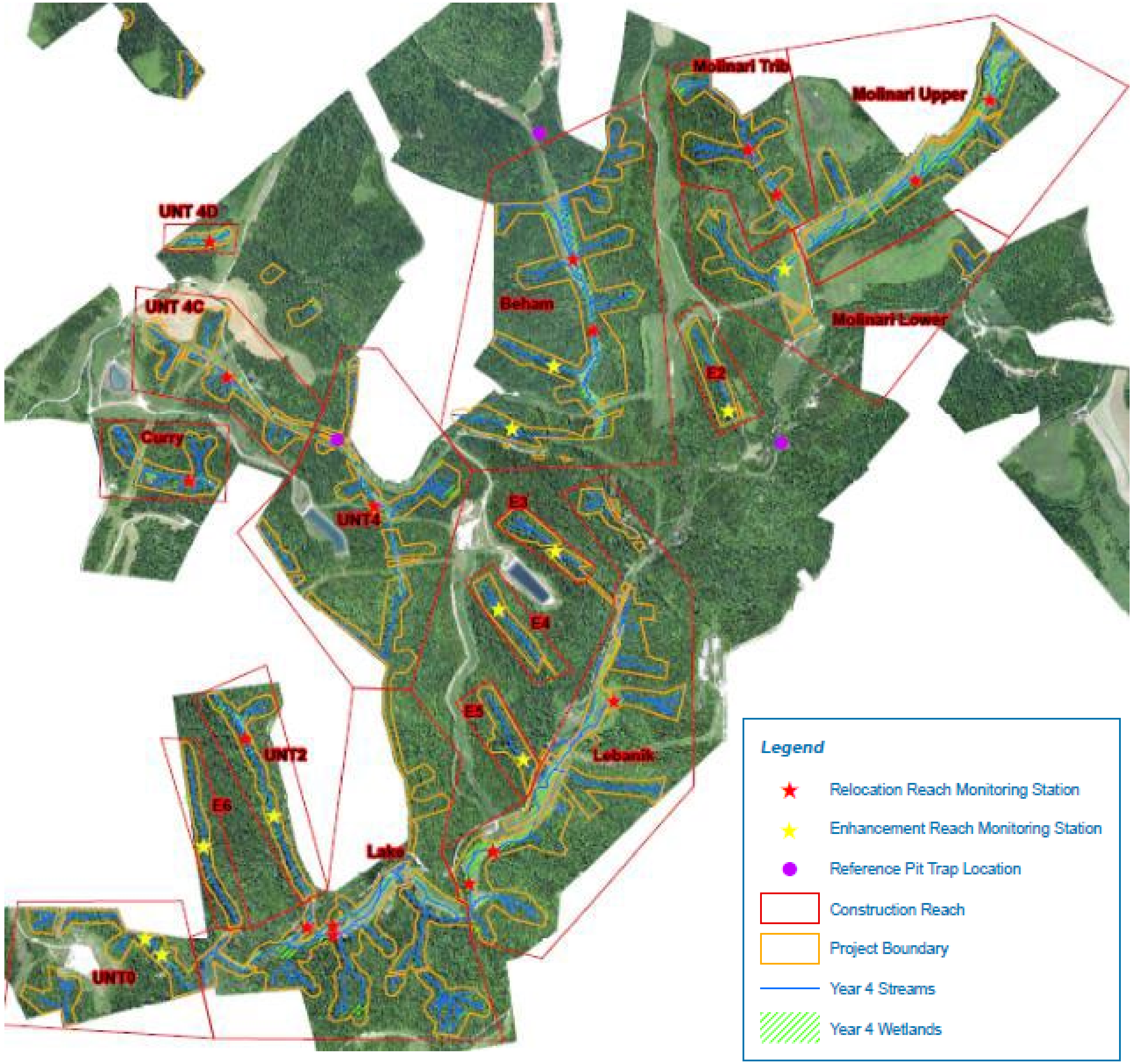
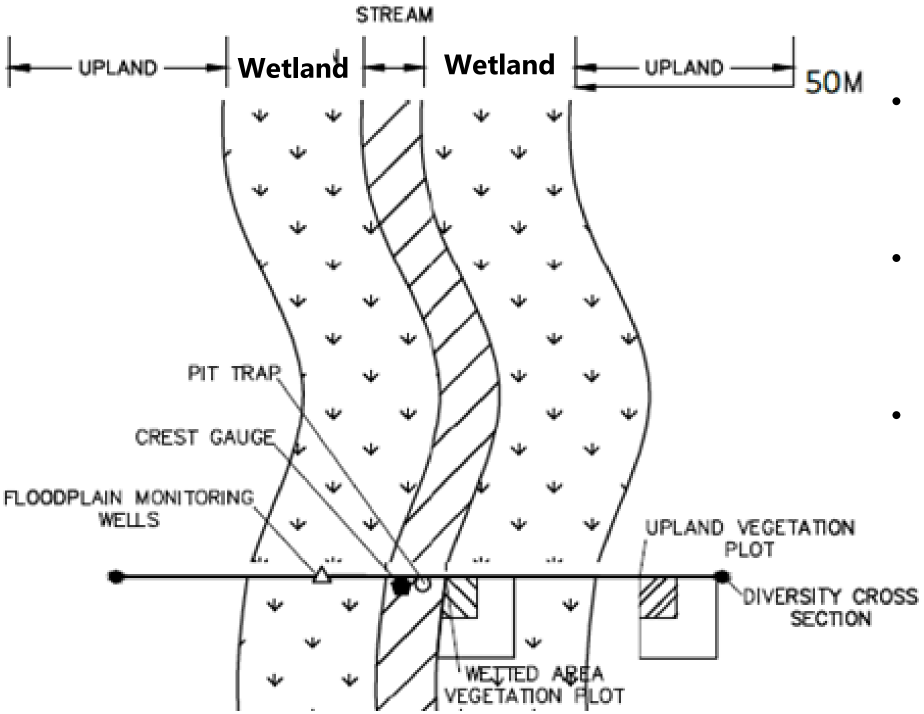
Monitoring Layout



- 17 Unique Construction Reaches
- 17 Restoration (Relocation/Rehabilitation) Reach Monitoring Stations
- 11 Enhancement (Geomorphic/Habitat) Reach Monitoring Stations

Monitoring Station Design

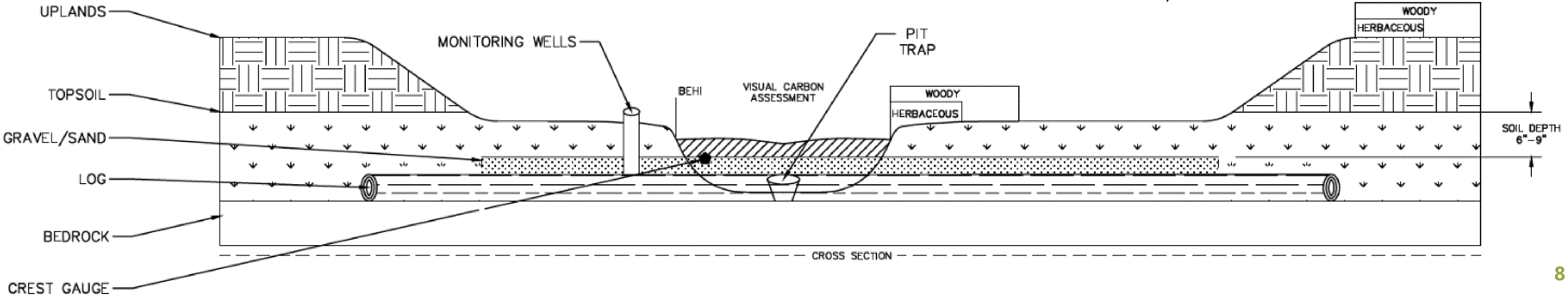


Wetland or Uplands

- Wetland/Upland Herbaceous Plot - 3′ x 3′
  - Species and Cover
  - Photos (C)
- Wetland/Upland Woody Plots -20′ Radius
  - Species, Cover, Heights, Condition
  - Photos (N, S, E, W)
- Wetland Monitoring Wells (Water Level Logger)

- **Streams**

- Stream Gauge (Water Level Logger)
- BEHI Evaluation
- Pebble Counts and Pit Traps
  - Habitat (Wolman – 100 Meter Reach – 100 Pebbles)
  - Stability (Riffle Transect – 100 Pebbles)
- LWD Volumes – 100 Meter Reach
  - >1.5 m x 10 cm
- Water Quality Samples
  - pH, Temp, DO, Turbidity, Specific Conductance
- Long Pro Survey – 100 Meter Reach
- Fish and Macroinvertebrate Surveys – 100 Meter Reach
- % Carbon/Sediment Retention and Instream Habitat Types



Performance Standards

Table 7: Performance Standards and Goals Summary					
Resource Type	Functional Subgroup	Evaluation	Performance Standard Value		
			Phase 1	Phase 2 If Different	Phase 3 If Different
Stream System	Vertical Bed Stability	Vertical Deviation	<0.5'	Same	Same
	Channel Pattern	Sinuosity	Within design range	Same	Same
	Channel / Floodplain Stability	BEHI	≤Low	Same	Same
	Channel / Floodplain Connectivity	Stream Hydrology	Bankfull ≥4/yr	Same	Same
Retention	Epifaunal substrate	Bed Mobility	≥50% pit trap reduction and/or improvement from reference	Same	Same
	Carbon / Sediment	Visual Retention Observation	≥ 60% carbon and/or sediment retention	Same	Same
	Habitat Diversity	LWD Volume	25% ↑ LWD habitat and/or substrate diversity	Same	Same
		Pebble Count Diversity			
	Biological	Fish	N/A	↑ species richness or 10% ↑ biomass, or #; and/or	Same
		Macros	N/A	10% ↑ IBI score	Same
Stream / Floodplain	Riparian Wetland	Invasive Vegetative Cover	≤15%	≤10%	≤5%
		Native Vegetative Cover	≥30%	≥50%	≥70%
		Woody Vegetative Cover	N/A	≥15%	≥30%
	Root Saturation	Groundwater Hydrology	12 consecutive days or 12% of growing season upper 1' soil saturation	Same	Same
	Stream Channel / Floodplain Diversity	Cross Section Diversity	↑ habitat diversity & depth/velocity regimes	Same	Same
Upland	Habitat	Invasive Vegetative Cover	≤15%	≤10%	≤5%

Results from Baseline

Comparable Data Review - BEHI										
Reach	Cross-section	Baseline Value	2017		2018		2019		2020	
			Value	Improvement?	Value	Improvement?	Value	Improvement?	Value	Improvement?
4D	1	Extreme	Low	Yes	Low	Yes	Not Sampled		Low	Yes
McCulley	1	High	Low	Yes	Low	Yes			Low	Yes
	2	High	Low	Yes	Low	Yes			Very Low	Yes
Upper Molinari	1	High	Low	Yes	Low	Yes			Low	Yes
	2	High	Low	Yes	Low	Yes			Low	Yes
Molinari Trib	1	Very High	Low	Yes	Low	Yes			Low	Yes
	2	High	Low	Yes	Low	Yes			Very Low	Yes
Lebanik	1	High	Not Sampled		Low	Yes	Very Low	Yes	Low	Yes
	2	Moderate			Low	Yes	Low	Yes	Very Low	Yes
	3	Moderate			Low	Yes	Low	Yes	Low	Yes
Lake Reach	1	High			Very Low	Yes	Low	Yes	Low	Yes
	2	Very High			Low	Yes	Low	Yes	Low	Yes
Beham	1	Very High			Low	Yes	Low	Yes	Low	Yes
	2	Moderate			Low	Yes	Low	Yes	Very Low	Yes
UNT2	1	Extreme			Low	Yes	Low	Yes	Low	Yes
Curry	1	High			Low	Yes	Low	Yes	Very Low	Yes
UNT4	1	High			Low	Yes	Low	Yes	Low	Yes
UNT4C	1	Extreme			Low	Yes	Low	Yes	Very Low	Yes

Comparable Data Review – LWD (m^3/m^2)										
Reach	Cross-section	Baseline Value	2017		2018		2019		2020	
			Value	Improvement?	Value	Improvement?	Value	Improvement?	Value	Improvement?
4D	1	0	0.0032	Yes	0.0032	Yes	Not Sampled		0.0032	Yes
McCulley	1	0.0025	0.0147	Yes	0.0147	Yes			0.0147	Yes
	2	0.0007	0.0337	Yes	0.0337	Yes			0.0337	Yes
Upper Molinari	1	0.0066	0.0011	-	0.0084	Yes			0.0084	Yes
	2	0.0066	0.0074	Yes	0.0080	Yes			0.0080	Yes
Molinari Trib	1	0.0009	0.0157	Yes	0.0157	Yes			0.0158	Yes
	2	0	0.0016	Yes	0.0016	Yes			0.0016	Yes
Lebanik	1	0.0002	Not Sampled		0.0249	Yes	0.0249	Yes	0.0249	Yes
	2	0.0012			0.0049	Yes	0.0049	Yes	0.0049	Yes
	3	0.0012			0.0062	Yes	0.0062	Yes	0.0062	Yes
Lake Reach	1	0.0001			0.0097	Yes	0.0103	Yes	0.0103	Yes
	2	0.0001			0.0144	Yes	0.0144	Yes	0.0145	Yes
Beham	1	0.0002			0.0107	Yes	0.0111	Yes	0.0111	Yes
	2	0.0003			0.0048	Yes	0.0048	Yes	0.0048	Yes
UNT2	1	0.0011			0.0317	Yes	0.0358	Yes	0.0358	Yes
Curry	1	0.0031			0.0246	Yes	0.0263	Yes	0.0263	Yes
UNT4	1	0.0064			0.0085	Yes	0.0095	Yes	0.0095	Yes
UNT4C	1	0			0.0327	Yes	0.0327	Yes	0.0327	Yes

Results from Baseline

Comparable Data Review – Macroinvertebrate IBI										
Reach	Cross-section	Baseline Value	2017		2018		2019		2020	
			Value	Improvement?	Value	Improvement?	Value	Improvement?	Value	Improvement?
4D	1	35.10	Not Sampled		47.53	Yes	Not Sampled		49.54	Yes
McCulley	1	49.92			37.08	-	49.58	-	67.46	Yes
	2	40.77			42.76	Yes	60.10	Yes	73.59	Yes
Upper Molinari	1	47.52			65.16	Yes	Not Sampled		55.29	Yes
	2	47.52			52.38	Yes			62.53	Yes
Molinari Trib	1	48.32			62.61	Yes			68.25	Yes
	2	35.19			70.73	Yes			65.61	Yes
Lebanik	1	37.08			Not Sampled		56.82	Yes	56.73	Yes
	2	42.83					42.97	Yes	47.08	Yes
	3	42.83					45.56	Yes	48.18	Yes
Lake Reach	1	42.41					39.07	-	50.77	Yes
	2	33.65					46.57	Yes	71.70	Yes
Beham	1	62.67					47.91	-	62.69	Yes
	2	54.48					57.37	Yes	66.89	Yes
UNT2	1	53.16					47.72	-	67.38	Yes
Curry	1	31.63					51.99	Yes	66.37	Yes
UNT4	1	50.53					51.18	Yes	65.10	Yes
UNT4C	1	35.1					66.71	Yes	49.64	Yes

Comparable Data Review – Fish										
Reach	Cross-section	Baseline Value	2017		2018		2019		2020	
			Value	Improvement?	Value	Improvement?	Value	Improvement?	Value	Improvement?
4D	1	None	Not Sampled		None	-	Not Sampled		None	-
McCulley	1	None			None	-			None	-
	2	None			None	-			None	-
Upper Molinari	1	Fish Present			Richness Increase	Yes			Richness Increase	Yes
	2	Fish Present			No Change	-			Richness Increase	Yes
Molinari Trib	1	None			Range Expansion	Yes			None	-
	2	None			Range Expansion	Yes			Range Expansion	Yes
Lebanik	1	None			Not Sampled		None	-	None	-
	2	Fish Present					No Change	-	No Change	-
	3	Fish Present					No Change	-	No Change	-
Lake Reach	1	Fish Present					Range Expansion/Biomass Increase	Yes	Range Expansion	Yes
	2	None					Range Expansion	Yes	Range Expansion	Yes
Beham	1	Fish Present					Richness Increase	Yes	Species Quality Increase	Yes
	2	Fish Present					Richness/Biomass Increase	Yes	Richness Increase	Yes
UNT2	1	None					Range Expansion	Yes	Range Expansion	Yes
Curry	1	None					None	-	None	-
UNT4	1	Fish Present					Biomass Increase	Yes	Biomass Increase	Yes
UNT4C	1	None					None	-	None	-

Outcome for Commercial Mitigation Banking

Compensatory Mitigation & Ecological Uplift

RES' Quaker Mitigation Bank, near Allentown, PA

Reestablishing base level control for the riverine and wetlands systems to exist on by undoing the historic and modern alterations.

Lower long-term costs (lower or no long-term maintenance or repairs)

Higher quality vegetation (low invasives) due to hydrology and conditions favorable for reestablishing native communities

Design for climate resilience where these conditions survived thousands of years of climatic variability and maintained their form, representing the best chance for surviving future changes in rainfall intensity.

EPA Publication on Dynamic Systems

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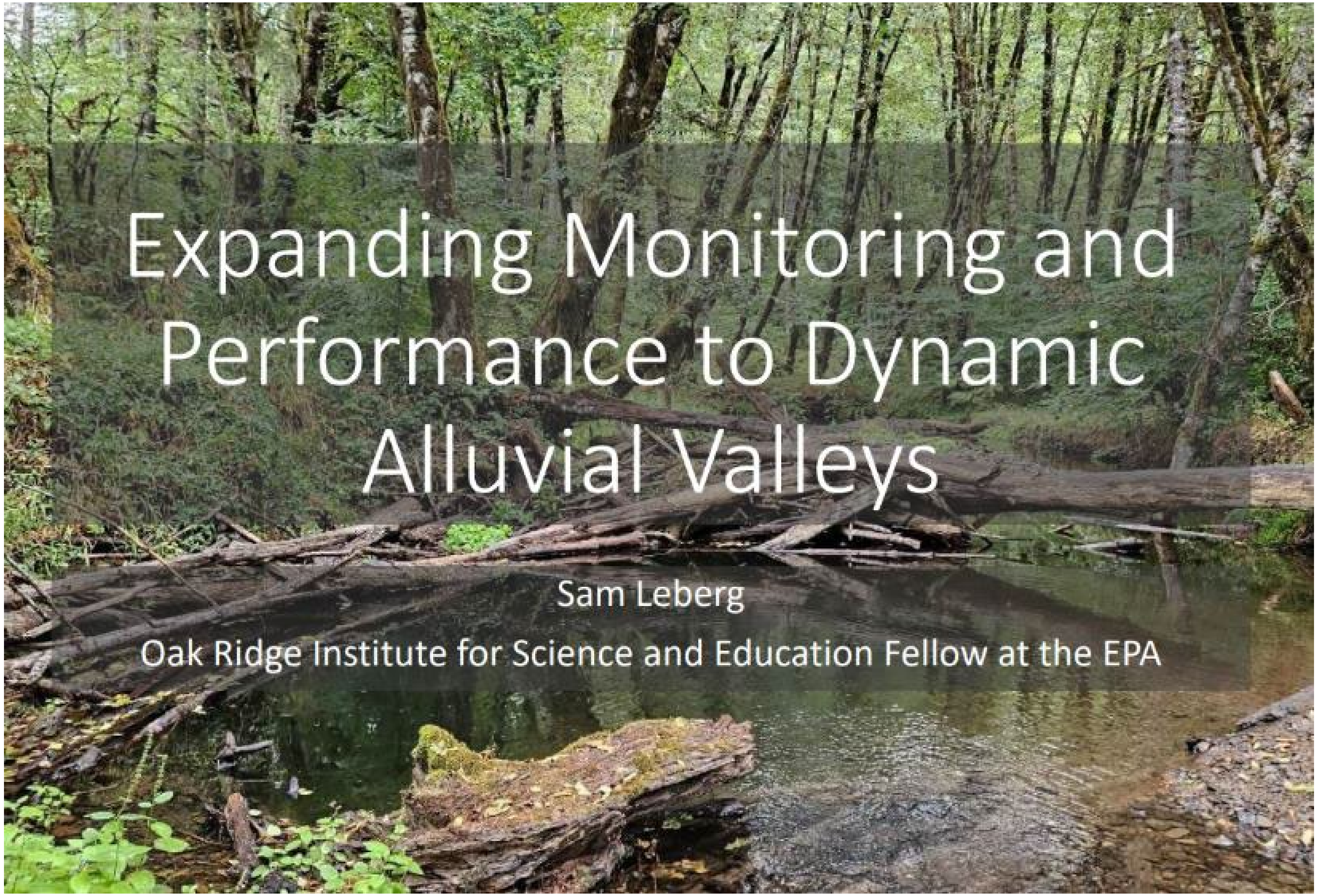
References

2023 NSRC Workshop

- https://restorestreams.org/2023-agenda

Mid-Atlantic Wetlands Workgroup 2023 Annual Meeting

- https://www.nawm.org/mawwg-2023-annual-meeting.html



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Expanding Monitoring and Performance to Dynamic Alluvial Valleys

Metric Organization

Key Process	Stream Function Pyramid Level	SFAM Key Functions	Parameter	Indicator	Citation
Extensive Lateral and Vertical Connectivity	Hydraulics	Surface water storage, sub/surface transfer, flow variation, sustain trophic structure, nutrient cycling, chemical regulation, thermal regulation	Groundwater and Surface Water Exchange	Monitoring wells	Robinson Fork Mitigation Bank, Quaker Mitigation Bank
	Geomorphology	Surface water storage, flow variation, sediment continuity, create and maintain habitat	Lateral Migration	Bank Erodibility Hazard Index (BEHI)	Upper Susquehanna River Mitigation Bank-Phase 2, Codorus Creek Stream & Wetland Bank
	Physicochemical	Surface water storage, sub/surface transfer, flow variation, thermal regulation,	Temperature	Surface or mean water temperature through water column- DM, MWAT, monthly average (summer or winter)	Great Pee Dee Mitigation Bank, Upper Susquehanna River Mitigation Bank-Phase 2, Pollock et al. 2003

Performance Metrics

Key Process	Parameter	Indicator	Target	Timing	Notes & Considerations
Extensive Lateral and Vertical Connectivity	Floodplain Connectivity	Flooding/Inundation frequency, duration, and/or aerial extent; stream gage, ground water wells, water presence sensors, other continuous monitoring	Floodplain inundation events or duration in a normal flow year	Monitored in all years	Indicative of a large flood-prone area frequently laterally connected. Specifics will vary by region. As used by practitioners in Pennsylvania, 4 times per year in a normal year, coupled with visual evidence of floodplain inundation in spring season.
Creation and Maintenance of Diverse Habitats	Depth Diversity	Coefficient of Variation of Depth	Increase compared to pre-project conditions; Meeting or exceeding reference conditions	Monitored in all years	Depth diversity indicates in-channel habitat and variable zones for temperature and sediment deposition. A matrix of stream depth can be created with aerial and multispectral imagery. Different depths can then be classified, and variation quantified. Restored DAVs should result in a high diversity of depths though specific numerical targets would be regionally-dependent.

Key Process	Parameter	Indicator	Target	Timing	Notes & Considerations
Retention of Materials	Carbon Retention	Visual, photo station or otherwise	60% of monitoring stations, pieces of LWD retaining CPOM	Monitored in all years	This metric target would demonstrate that a site can retain carbon but would not necessarily demonstrate successive carbon retention. The target will vary by region and site-specific conditions and should only apply to a normal flow year.
Abundant Biological Communities	Amphibian Communities	Native abundance	Native quantity increase compared to control reach	Monitored in all years after the first	Retentive systems will result in a larger wetted area that may support more amphibians. Particularly in headwater streams, amphibian metrics may more reliable than fish metrics. For amphibian metrics, sample the perimeter of the reach as well as the underside of logs.

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Ohio University Research on Robinson Fork

Agenda:

- Introduction
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- **OU Research on Robinson Fork**

Floodplain Reconnection Stream Restoration Increases Water and Nutrient Retention

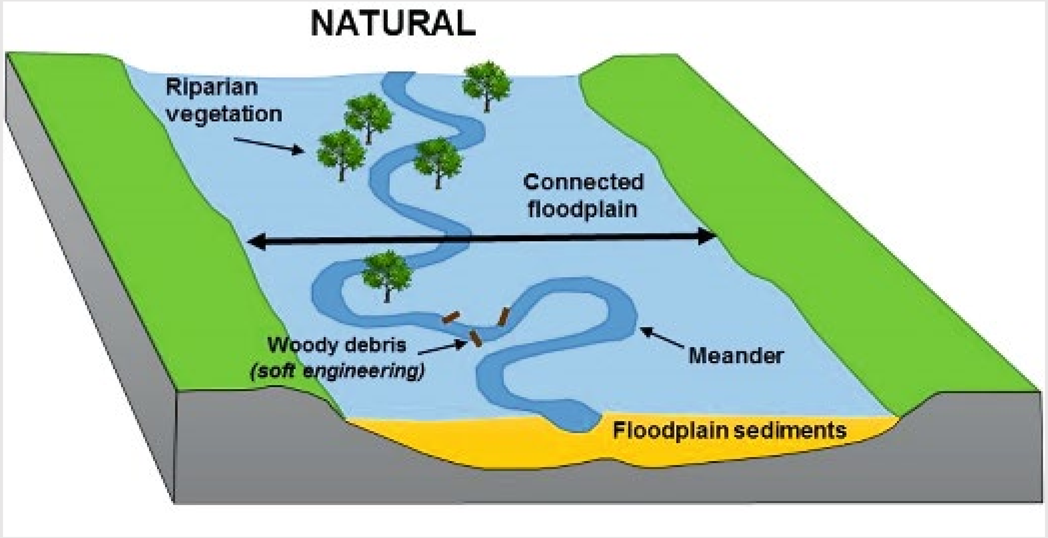
Presenter: Dr. Natalie Kruse Daniels

Annika Gurrola, Tatiana Burkett, Red Pazol, Nora Sullivan, Jen Bowman, Kelly Johnson, Morgan Vis

Ohio University

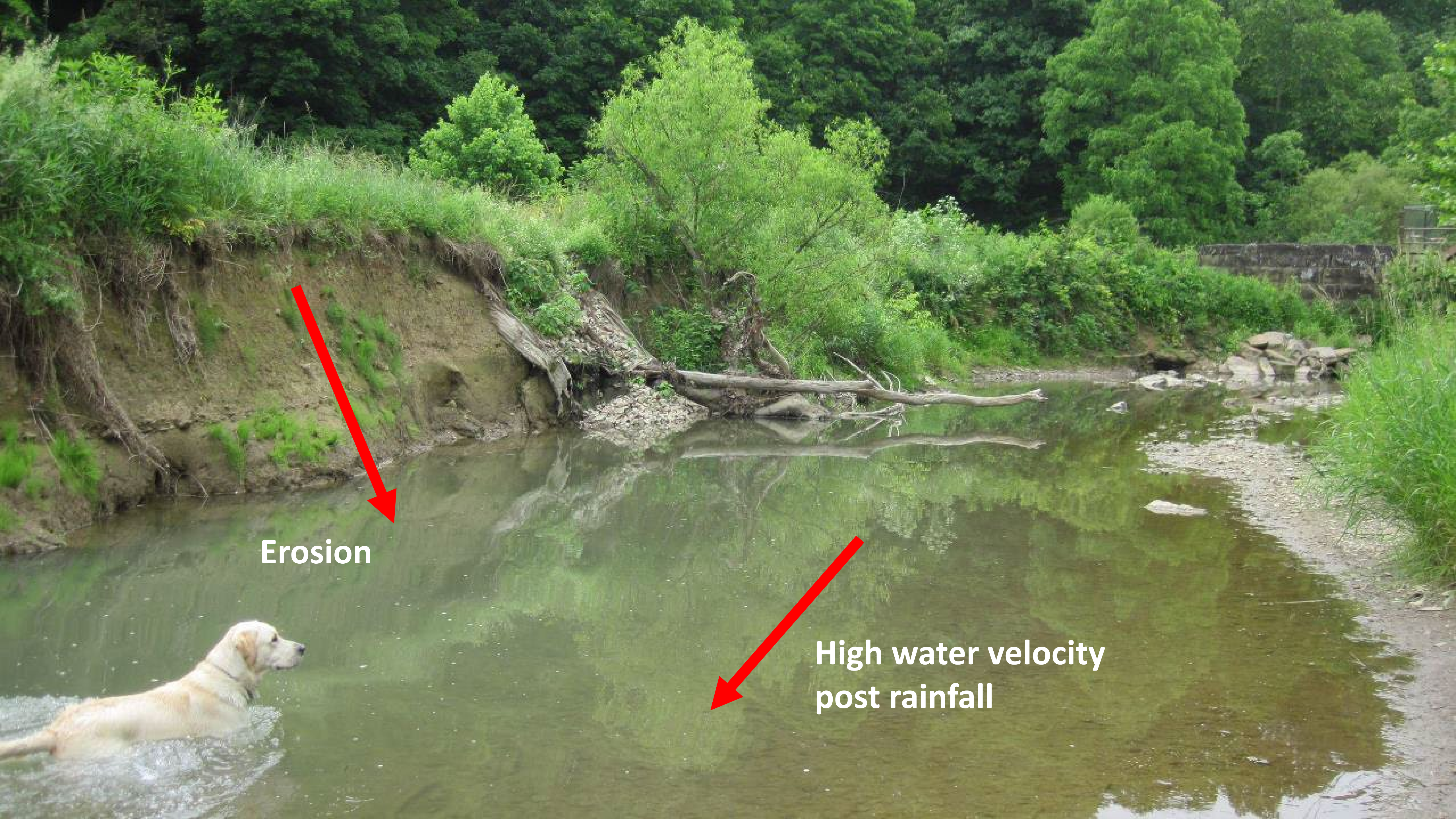
Floodplain Reconnection and Restoration

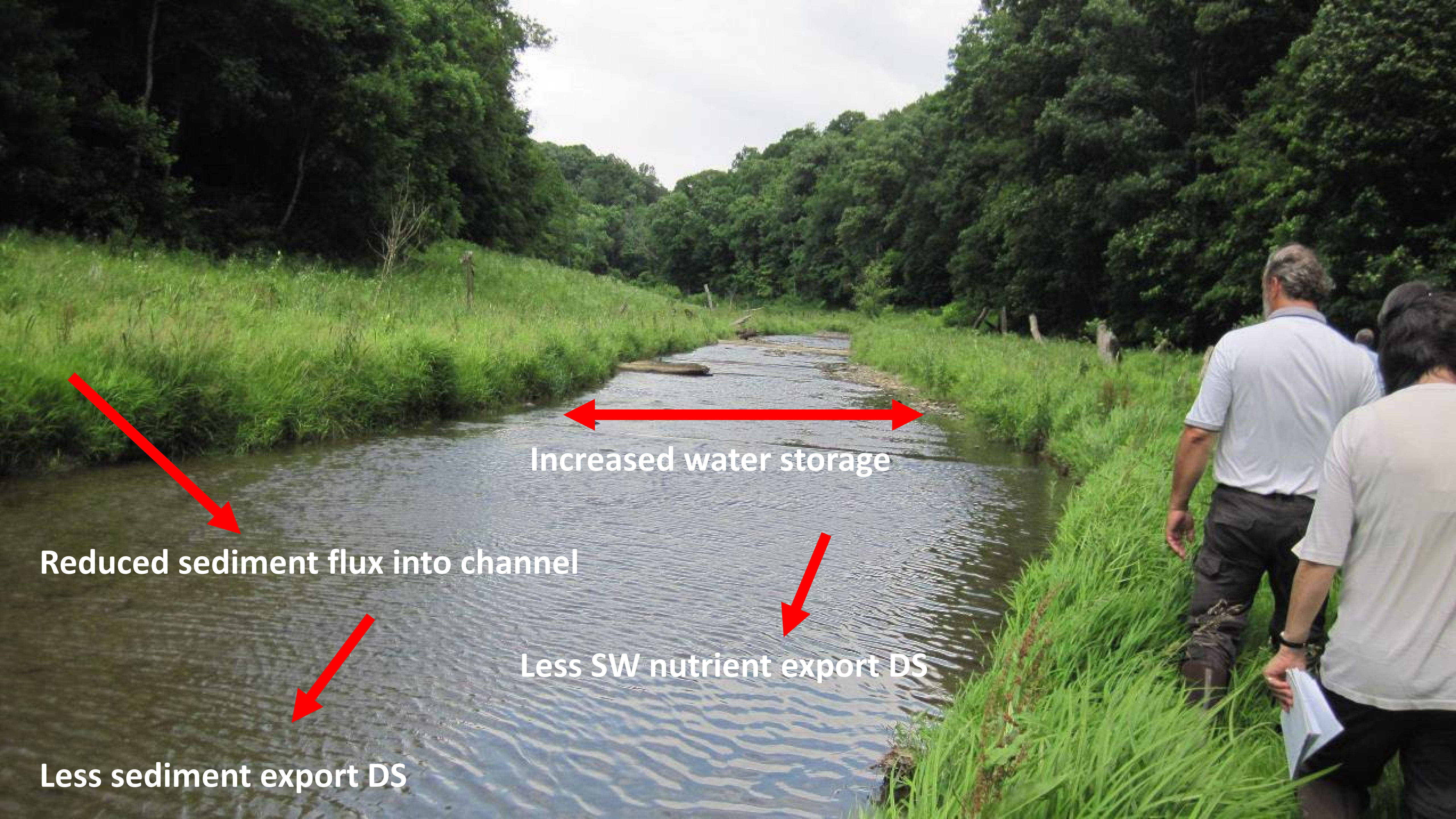
- Purpose
  - To reestablish connections between the stream channel, groundwater, and floodplain
- Why we're using it
  - Manage stream loss from longwall mining
  - Mitigation for mining & oil and gas
    - Increased water storage
    - Increased nutrient storage
    - Increased resilience to flooding
    - Reduced erosion
  - We know that the riverine and wetlands systems functioned and looked like this from in-situ buried evidence which provides information about how these resources existed for thousands of years before colonial and modern impacts severely altered them.



Cooper, Hiscock, & Lovett, 2019

RES' Middle Creek restoration, near Reading, PA

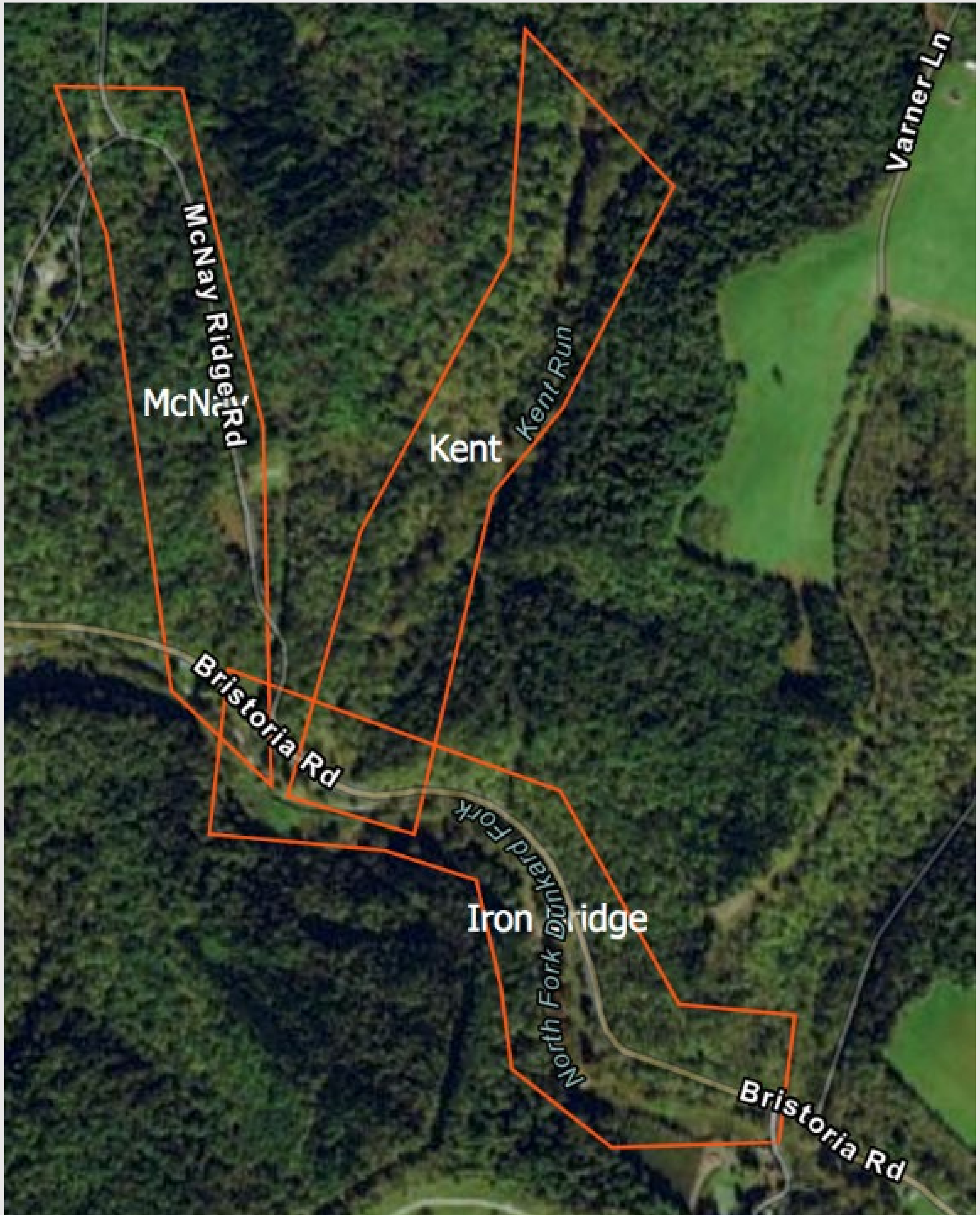

Erosion
High water velocity
post rainfall

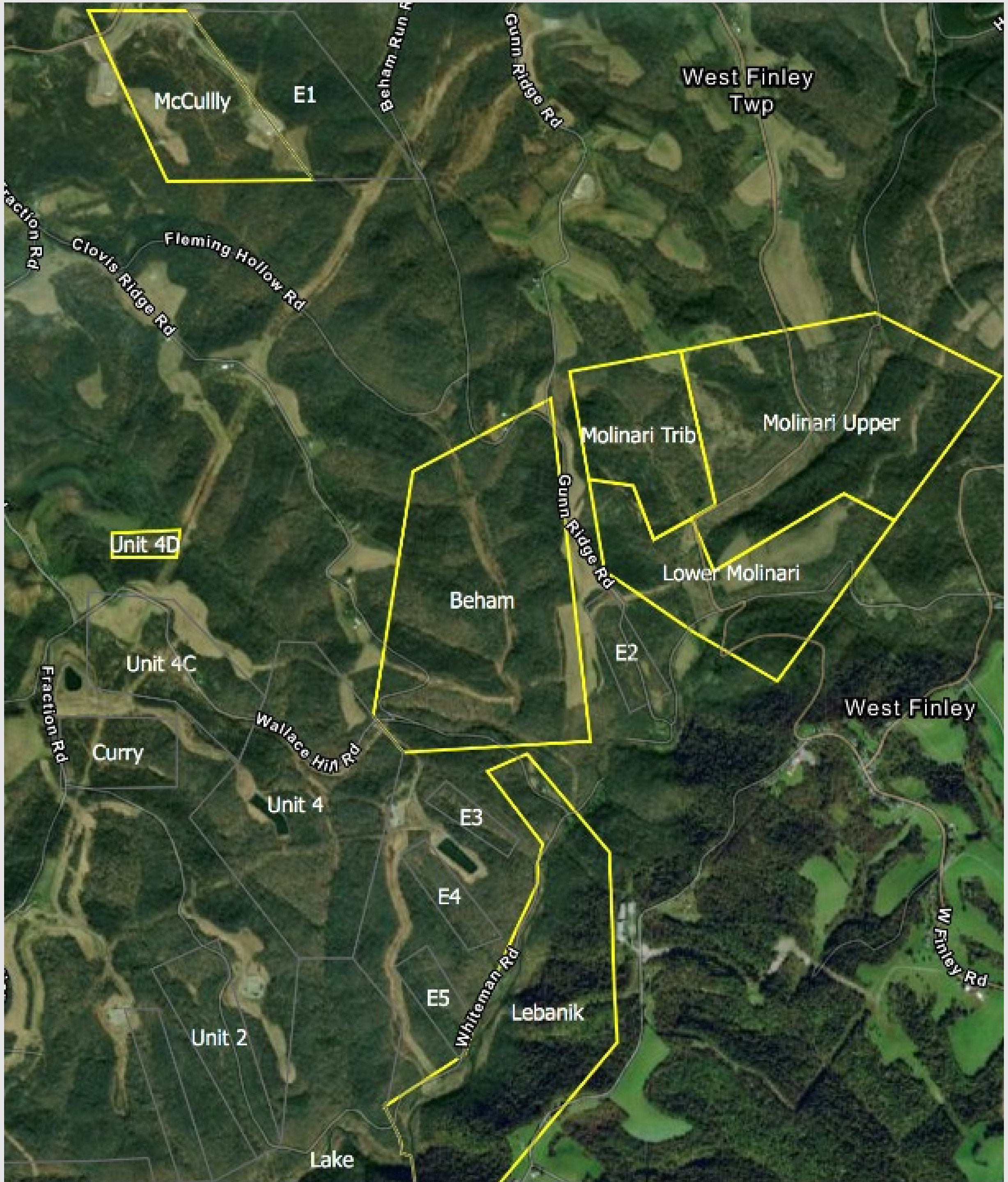

Increased water storage
Reduced sediment flux into channel
Less SW nutrient export DS
Less sediment export DS

Objectives

Characterize impact of the floodplain reconnection method in longwall mined watersheds by comparing the following characteristics of restored and unrestored sites

- Water storage
- Sediment retention and export
- N and P retention and export in the sediment and surface water
- Carbon accumulation and retention


McNay
McNay Ridge Rd
Kent
Kent Run
Varner Ln
Bristoria Rd
North Fork Dunkard Fork
Iron Bridge
Bristoria Rd


McCullly
E1
Beham Run Rd
Gunn Ridge Rd
West Finley Twp
Fraction Rd
Clovis Ridge Rd
Fleming Hollow Rd
Molinari Trib
Molinari Upper
Unit 4D
Gunn Ridge Rd
Lower Molinari
Beham
E2
Unit 4C
Fraction Rd
West Finley
Wallace Hill Rd
Curry
Unit 4
E3
E4
W Finley Rd
E5
Whiteman Rd
Lebanik
Unit 2
Lake

Study Sites

Primary headwaters

Headwaters

Wadeable

Results

- Rainfall, Flow, Water Storage
- Nutrients in Water, Pore Water, and Sediment
- Carbon Input and Storage

Conclusions

Water storage

- Slightly increased in restored sites

Sediment

- Higher proportion of fine-grained sediment at restored sites
- DS TSS load was driven by flow

Nutrients

- Sediment: Richer in N and P in restored sites
- Surface water N&P seasonal or flow dependent
- P storage in wetlands (pore water)

Conclusions

Total organic carbon	Carbon Input	Soil organic matter
• Dependent upon season (greater in the growing season), not restoration status	• Not significantly different between restoration status	• Greater in restored sites than unrestored

Thank you

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